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Two tropical species of *Stephanotheca* (Bryozoa, Cheilostomata, Lanceoporidae) from the Gulf of Carpentaria, Australia

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Abstract

Two new species of *Stephanotheca* are described from the southeast Gulf of Carpentaria, northern Australia, providing the first tropical records of this genus. *Stephanotheca ipsum* n. sp. is provisionally placed in the genus on the basis of a low ridge of calcification around the edge of the ooecium, which differs from the fully pseudoporous ooecium of *Calyptotheca* (Lanceoporidae) and resembles the ‘crowned’ ooecium of *Stephanotheca*, with a central porous area surrounded by a nodular imperforate area. *Stephanotheca ipsum* and *Stephanotheca romajoyae* n. sp. are the only species in the genus with more than one avicularium on some zooids. The latter species is distinguished by high variability in avicularium size, shape, position and orientation; it also shares dimorphic avicularia with *S. ochracea* (Hincks) and is the only species in which they sometimes occur together on the same zooid. This study increases the number of Australian *Stephanotheca* species to four. The Australian species all have smaller primary orifices and variations in ovicell morphology compared with other, all European, species. In *S. ipsum* n. sp. the ooecia are ridged, those of *S. victoriensis* Reverter-Gil *et al.* have a single row of pseudopores forming an arch, and those of *S. ambita* (Waters) and *S. romajoyae* n. sp. have a relatively large pseudoporous area and smaller, lower nodular imperforate area. None of the Australian species have vicarious avicularia, which are known only from the type species, *S. barrosoi* Reverter-Gil *et al.*

Key words: Tropical Australia, Indo-West Pacific, *Calyptotheca*

Introduction

Stephanotheca Reverter-Gil, Souto & Fernández-Pulpeiro, 2012 was erected for nine temperate species previously assigned to *Schizomavella* Canu & Bassler, 1917 (Bitectiporidae), six from the Mediterranean, one from the North Atlantic and two from southern Australia (Victoria and New South Wales). *Stephanotheca* was placed in the Lanceoporidae on the basis of cleithral ovicells, dimorphic orifices, vicarious avicularia (in the type species) and the structure of the ovicell. Within the Lanceoporidae, *Stephanotheca* is closest to *Calyptotheca* Harmer, 1957, with which it shares a sinus, adventitious avicularia and vicarious avicularia. *Emballotheca* Levinsen, 1909 lacks a sinus, and *Lanceopora* d'Orbigny, 1851 lacks adventitious avicularia and has erect, stalked and rooted colonies. The most obvious distinguishing character for *Stephanotheca* is the ooecium, which is ‘crowned’, having a circular or semicircular nodular ridge of calcification that resembles a crown, and perforations in a central area only (Reverter-Gil *et al.* 2012), whereas the ooecium of *Calyptotheca*, *Emballotheca* and *Lanceopora* is evenly perforated.

Only a handful of bryozoan species have been described from tropical Australia west of Torres Strait, which is more than a quarter of Australia's coastline (Cumming & Tilbrook 2014). Cumming & Tilbrook (2014) described six species of *Calyptotheca* from the Gulf of Carpentaria (GoC) Collection held at Museum of Tropical Queensland, Townsville. This study describes two species of *Stephanotheca* from this collection, and is the first record of tropical species of *Stephanotheca*.

Material and methods

Collection details and description of substratum types in the southeastern GoC are given by Cumming & Tilbrook (2014). Samples were prepared for scanning electron microscopy (SEM) by soaking in 10% bleach for 3–4 hours and coating with gold. Adobe Photoshop and GIMP 2.6.10 GNU Image Manipulation Program (1995–2008) were used to adjust the contrast and brightness of images, and GIMP was used for measurements on SEM images.

Taxonomy

Order Cheilostomata Busk, 1852

Suborder Neocheilostomina d'Hondt, 1985

Superfamily Smittinoidea Levinsen, 1909

Family Lanceoporidae Harmer, 1957

Genus *Stephanotheca* Reverter-Gil, Souto & Fernández-Pulpeiro, 2012

Type species. *Stephanotheca barrosoi* Reverter-Gil, Souto & Fernández-Pulpeiro, 2012, by original designation.

Remarks. Reverter-Gil *et al.* (2012) provisionally placed *Stephanotheca* in the Lanceoporidae, recognising that the genus shares characters with both the Lanceoporidae and the Bitectiporidae. It shares cleithral ovicells, orifice dimorphism, vicarious avicularia and cormidial secondary calcification with the Lanceoporidae, and the crowned ooecium with *Hippoporina* and *Schizomavella* (Bitectiporidae).

All nine temperate species of *Stephanotheca* described by Reverter-Gil *et al.* (2012) have a single, medial, proximally directed adventitious avicularium (sometimes wanting in some species). The two tropical species described here differ in having more than one avicularium on some zooids. In addition, *S. romajoyae* **n. sp.** is unique in having dimorphic avicularia (small and very large forms, the latter occupying most of the frontal shield), sometimes occurring on the same zooid.

Stephanotheca ipsum **n. sp.**

(Figure 1, Table 1)

Material Examined. *Holotype:* MTQ G26766, southeastern GoC, 16°40.914' S, 140°12.092' E, encrusting *Cigclisula* sp., 33 m. *Paratypes:* MTQ G26767, encrusting *Cigclisula*, same data as for holotype; MTQ G26768, eastern GoC, seabed surrounding submerged coral reef, 15°15.561' S, 140°22.905' E, encrusting *Steginoporella* sp., 49 m.

Etymology. From the Latin *ipsum* for button, for the button-like roundness of the primary orifice, the sinus and the adventitious avicularia.

Description. Colony encrusting; autozooids irregularly hexagonal (c. 0.4 x 0.3 mm; Table 1); frontal shield flattened to slightly convex; pseudopores relatively small (c. 0.008 mm diameter) and widely spaced, separated by more than two pseudopore diameters (c. 43 per zooid), rounded to elongate, extending to zooid margins; interzooidal boundaries marked by thin grooves and occasional elongate sutural pores; walls between zooids with 3–4 uniporous septula.

Primary orifice as wide as long (c. 0.10 x 0.10 mm); anter round; lunula restricted to distal half of orifice; sinus a wide rounded arc; condyles large, elongate, serrate.

Each zooid with a single, small, round, suboral, medial adventitious avicularium (c. 0.04 mm diameter), cystid raised proximally, directed proximofrontally; proximal opesia and rostral foramen oval; mandible semicircular; crossbar complete; sometimes one, rarely two, additional avicularia of same shape and size proximally, adjacent to orifice of an adjacent zooid, directed distolaterally; vicarious avicularia not observed.

Ooecium wider than long (c. 0.3 x 0.2 mm), immersed, bordered by ridge of calcification that is sometimes

complete, sometimes restricted to distal edge, not crossed by suture lines; orifice dimorphic, the ovicellate orifice significantly wider than autozooidal orifice (c. 0.12 vs 0.10 mm; 1-tailed t-test: $p < 0.001$; Table 1).

TABLE 1. Measurements (mm) and counts for *Stephanotheca ipsum n. sp.* Zoid, orifice, avicularia and ovicell measurements on holotype (MTQ G26766), pseudopore measurements on MTQ G26768.

	Mean	Standard deviation	Range	N
Zoid length	0.446	0.060	0.369–0.558	10
Zoid width	0.256	0.063	0.190–0.353	10
Autozooid orifice length	0.096	0.004	0.090–0.101	10
Autozooid orifice width	0.100	0.003	0.094–0.104	10
Adventitious avicularium length	0.040	0.003	0.035–0.045	10
Adventitious avicularium width	0.039	0.001	0.038–0.042	10
Diameter of pseudopores in frontal shield	0.008	0.001	0.007–0.010	10
Number of pseudopores in frontal shield	43.4	4.648	36–49	10
Ooecium length	0.218	0.027	0.188–0.247	5
Ooecium width	0.274	0.062	0.211–0.376	5
Ovicellate orifice length	0.087	0.003	0.085–0.090	3
Ovicellate orifice width	0.117	0.007	0.113–0.126	3

Remarks. *Stephanotheca ipsum n. sp.* is distinguished by its rounded orifice with semicircular sinus, small, round avicularia suborally and proximally, and the extensively pseudoporous ooecium with a low ridge of peripheral calcification. It shares with other *Stephanotheca* species an encrusting growth form and a proximally directed, medial adventitious avicularium. No other *Stephanotheca* species have more than one adventitious avicularium per zooid, except *S. romajoyae n. sp.*

Stephanotheca ipsum n. sp. is provisionally placed in *Stephanotheca* on the basis of the ridged ooecium, which differs from the fully pseudoporous ooecium of *Calyptotheca* and resembles the crowned ooecium of *Stephanotheca* in having a porous area surrounded by an imperforate area. On the one hand, it resembles *S. perforata* Reverter-Gil, Souto & Fernández-Pulpeiro, 2012, from the Mediterranean, which also has a ridged ooecium instead of the crowned ooecium typical of European *Stephanotheca*, but only one ooecium was present in the material and the morphological variability is unknown (Reverter-Gil *et al.* 2012). On the other hand, it resembles *C. inclusa* (Thornely, 1906), an Indo-Pacific species, which has a single, near-circular, suboral medial avicularium on each zooid and ooecia with a ridge [called a “calcareous arch” by Thornely (1905, p. 116, plate, fig. 2, as *Schizoporella avicularis*)]. However, Harmer (1957, p. 1029, pl. 66, fig. 4) noted *C. inclusa* specimens were only “sometimes bordered by a smooth, semicircular ridge”. This feature has not appeared in subsequent descriptions and illustrations of *C. inclusa* by Ristedt & Hillmer (1985), Winston & Heimberg (1986), Hayward (1988), Scholz (1991), Ryland & Hayward (1992) and Tilbrook (2006). *Stephanotheca perforata* differs from *S. ipsum n. sp.* in having a much larger orifice (0.15 x 0.15 mm vs 0.10 x 0.10 mm), more numerous and more closely spaced pseudopores in the frontal shield (approx. 75 vs mean 43), and only a single, oval avicularium, often wanting, whereas *S. ipsum* has up to three round avicularia on each zooid, one suborally and one or two proximally. *Calyptotheca inclusa* differs from *S. ipsum n. sp.* by its pear-shaped orifice with deeper, narrower sinus, larger, more oval suboral avicularia with trifoliate distal opesia, no proximal adventitious avicularia, and occasional vicarious avicularia.

Calyptotheca inclusa belongs to a group of similar species with a single, oval or round, suboral, medial avicularium on each zooid. Of these, *C. immersa* (Powell, 1967), *C. lardil* Cumming & Tilbrook, 2014, *C. reniformis* Tilbrook, 2006 and *C. rugosa* Hayward, 1974 (p. 379, fig. 5a) have the fully perforated ooecia of *Calyptotheca*, but ooecial details are not known for *C. kapaaensis* Dick, Tilbrook & Mawatari, 2006, *C. subimmersa* (MacGillivray, 1879), *Schizomavella collina* Cook, 1965 and *S. incompta* Hayward, 1988 (p. 315, pl. 7e), in most cases because ooecia were not present in the material. It remains possible that some of these latter species have ridged ooecia. Only one of these, *S. incompta*, has additional proximal avicularia, but unlike those of *C. ipsum n. sp.*, they are dimorphic, the proximal avicularia being triangular and larger.

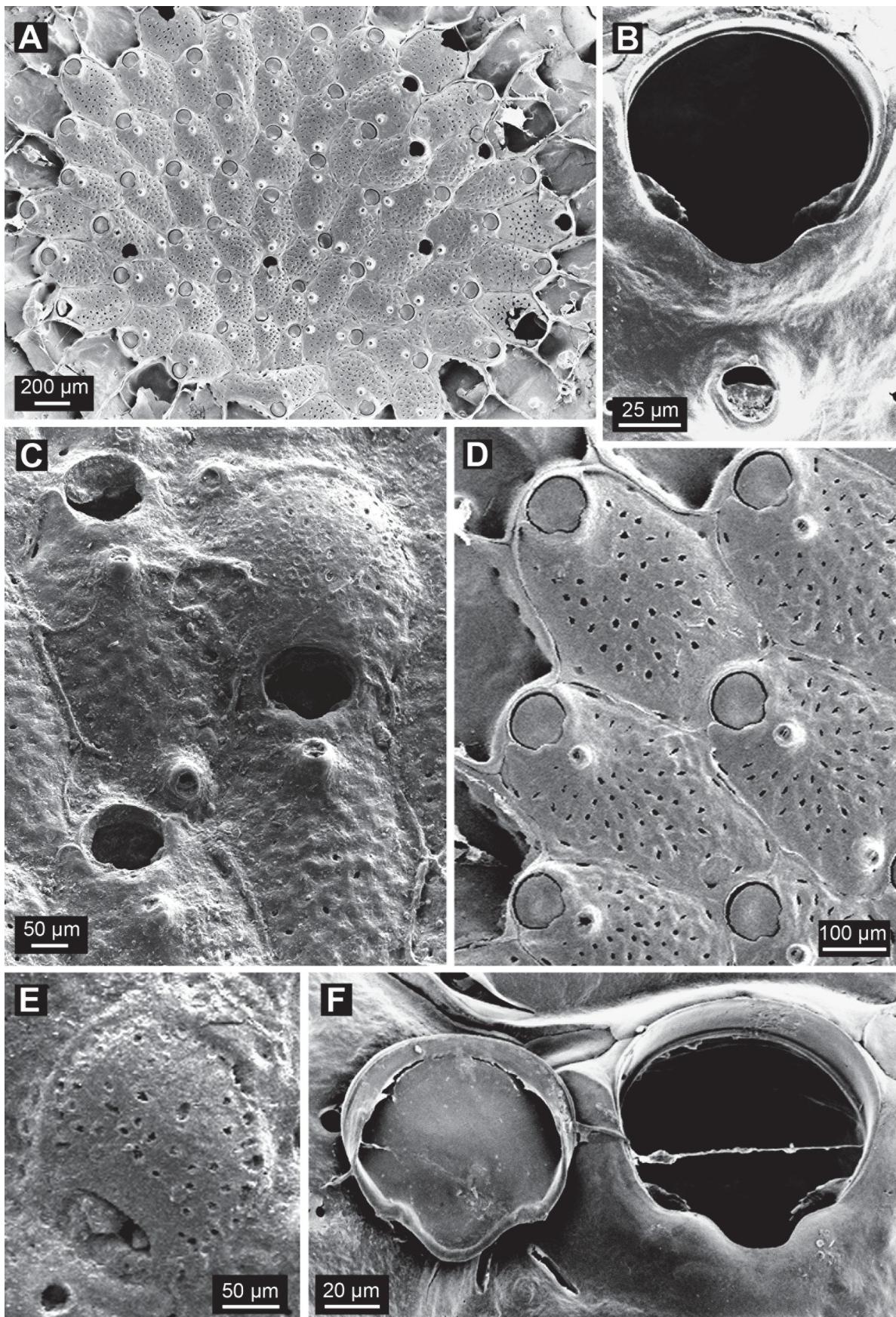


FIGURE 1. *Stephanotheca ipsum* n. sp. **A, B, D, F**, paratype (MTQ G26768); **C, E**, holotype (MTQ G26766): **A**, whole colony; **B**, primary orifice with suboral avicularium; **C**, autozooid and ovicellate zooid; note the ridged oocium; **D**, marginal autozooids; note septula in lateral walls; **E**, oocium; **F**, primary orifice with operculum.

The ooecia of the two southern Australian *Stephanotheca* species, *S. ambita* Reverter-Gil, Souto & Fernández-Pulpeiro, 2012 and *S. victoriensis* Reverter-Gil, Souto & Fernández-Pulpeiro, 2012, also vary from the typical crowned ooecium of the European species. Those of *S. ambita* have a relatively larger perforated area and smaller, lower nodular rim of calcification, which is nevertheless larger than the ridge of *S. ipsum n. sp.* and *S. perforata*. Those of *S. victoriensis* are neither crowned nor ridged, but instead have a wide arch of pseudopores, and a few pseudopores scattered frontally. *Stephanotheca victoriensis* is only provisionally placed in the genus (Reverter-Gil *et al.* 2012). *Stephanotheca ambita* shares with *S. ipsum n. sp.* a relatively small round orifice with wide, shallow sinus, and small, suboral, proximofrontally directed avicularia, but differs in having non-serrate condyles, oval rather than round avicularia, only one avicularium per zooid, and different ooecial morphology. *Stephanotheca victoriensis* has a wider, distinctly oval orifice, a single, oval, much larger avicularium distant from the orifice and almost in the centre of the zooid, and different ooecial morphology.

Distribution. *Stephanotheca ipsum n. sp.* is known only from the GoC. Two colonies are from the same site east of Mornington Island in the southeastern GoC, encrusting the foliaceous habitat-providing bryozoan *Cigclisula* sp. at 33 m. The third colony is from the seabed surrounding a submerged coral reef in the eastern GoC, encrusting the platelike habitat-providing bryozoan *Steginoporella* sp. at 49 m.

Stephanotheca romajoyae n. sp.

(Figure 2, Table 2)

Material examined. Holotype: MTQ G26769, Bryomol Reef, 16°32.658' S, 139°53.567' E, 33 m. Paratypes: MTQ G26770, MTQ G26771, MTQ G26772, same data as for holotype; MTQ G26773, southeastern GoC, 16°40.914' S, 140°12.029' E, 33 m.

Etymology. Named for the author's mother, Mrs Roma Joy Cumming.

Description. Colony encrusting, with frontal budding; autozooids irregularly polygonal, variable in size and shape (average 0.4 × 0.4 mm; Table 2), especially variable in width (s.d. 0.117); frontal shield flattened to slightly convex; pseudopores round, irregularly spaced (c. 0.012 mm diameter), most separated by more than the width of a pseudopore but some close together and sharing depressions or pits (average 47 per zooid), extending to zooid margins; interzooidal boundaries marked by sutural walls and regularly spaced, oval or round sutural pores that are larger than pseudopores in the frontal shield.

TABLE 2. Measurements (mm) and counts for *Stephanotheca romajoyae n. sp.* holotype (MTQ G26769).

	Mean	Standard deviation	Range	N
Zooid length	0.373	0.042	0.299–0.470	20
Zooid width	0.363	0.117	0.243–0.796	20
Autozooid orifice length	0.087	0.005	0.075–0.094	17
Autozooid orifice width	0.103	0.005	0.096–0.112	17
Small adventitious avicularium length	0.092	0.011	0.080–0.114	20
Small adventitious avicularium width at crossbar	0.040	0.004	0.034–0.048	20
Large adventitious avicularium length	0.283	0.009	0.276–0.289	2
Large adventitious avicularium width at crossbar	0.074	0.005	0.071–0.078	2
Diameter of pseudopores in frontal shield	0.012	0.002	0.008–0.015	20
Number of pseudopores in frontal shield	47	10.75	35–70	20
Ooecium length	0.392	0.014	0.369–0.406	5
Ooecium width	0.302	0.027	0.276–0.332	4
Ooecium height	0.057	0.023	0.041–0.073	2
Ovicellate orifice length	0.107	0.012	0.099–0.116	2
Ovicellate orifice width	0.140	0.004	0.135–0.144	4

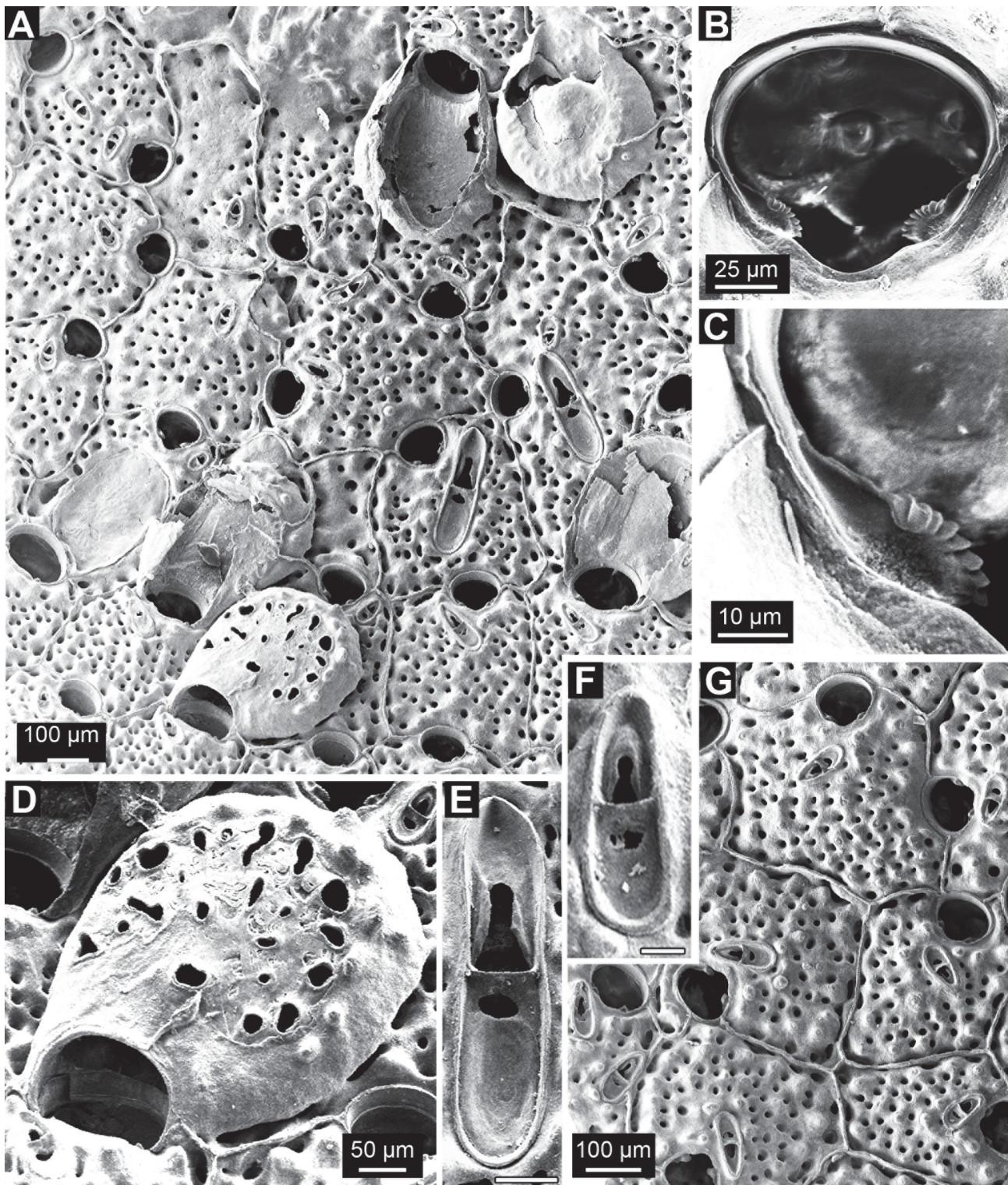


FIGURE 2. *Stephanotheca romajoyae* n. sp. holotype (MTQ G26769): A, general view with autozooids and ovicellate zooids; note dimorphic orifices, additional avicularia on some zooids, and irregularly spaced pseudopores, some sharing pits (see zooid lower centre with large avicularium); B, primary orifice; C, orificial condyle; note serrations; D, ooecium; note ring of nodules and irregularly shaped pseudopores; E, large adventitious avicularium (scale bar 50 µm); F, small adventitious avicularium (scale bar 20 µm); G, autozooids; note unusual proximolaterally directed avicularia, and autozooid with two avicularia.

Primary orifice wider than long (c. 0.09 long \times 0.10 wide mm), broadest centrally; anter rounded; lunula extends to lateral margins and appears continuous with condyles; sinus a shallow arc; condyles large, rounded, serrate; a raised nodular thickening proximal to orifice.

Adventitious avicularia dimorphic in size, shape and position; usually one per zooid, occasionally two; smaller type common (c. 0.09 long \times 0.04 wide mm at crossbar); subtriangular; widest proximally; proximal opesia semicircular, rostral foramen trifoliate to rounded triangular; crossbar complete; usually suboral, medial, directed distolaterally; sometimes with slight asymmetry, curving towards orifice; occasionally directed proximolaterally or positioned in a distolateral corner; occasional second avicularium positioned more proximally with variable orientation; larger type uncommon, occupying most of frontal shield (c. 0.28 long \times 0.07 wide mm at crossbar); elongate oval with parallel sides; proximal opesia oval, rostral foramen rounded subtriangular with concave sides; crossbar complete; usually proximal, medial, directed distolaterally, terminating in a distolateral angle; vicarious avicularia absent.

Ovicell hyperstomial (prominent), recumbent on frontal shield of distal zooid; ooecium longer than wide (c. 0.4 \times 0.3 mm); flattened frontally; with numerous pseudopores of variable shape and size, larger than those of frontal shield; an arch of nodules surrounding the pseudopores, terminating laterally; walls almost vertical, imperforate (height c. 0.06 mm); orifice dimorphic, ovicellate orifice longer (c. 0.11 vs. 0.09 mm) and much wider (c. 0.14 vs. 0.10 mm; Table 2) than autozooidal orifice (1-tailed t-test: p<0.001).

Remarks. The variability in avicularium size, shape, position and orientation sets *Stephanotheca romajoyae* n. sp. apart from all other *Stephanotheca* species. The nine temperate species described by Reverter-Gil *et al.* 2012 all have a single, medial, proximally directed adventitious avicularium. While *S. romajoyae* n. sp. also has a medial avicularium on each zooid, these vary in orientation from distolateral to proximolateral, there are also occasional additional avicularia elsewhere on the zooid, and occasional large elongate-oval avicularia that occupy most of the frontal shield. Sometimes the two different avicularium types occur together on a single zooid (Figure 2A). *Stephanotheca ipsum* n. sp. is the only other *Stephanotheca* species with more than one avicularium on some zooids, but they are a distinctly different shape and are not dimorphic. *Stephanotheca ochracea* (Hincks, 1862) is the only other species with dimorphic adventitious avicularia, but they are a different shape and proximally directed.

The level of variability in the avicularia of *Stephanotheca romajoyae* n. sp. resembles that of *Calyptotheca australis* (Haswell, 1880) in the dimorphism, the variable orientation and in sometimes being slightly asymmetrical and curved around the orifice (see Cumming & Tilbrook 2014). These two species also share similar small orifices of the same dimensions (c. 0.09 \times 0.10 mm) and large, serrate condyles. The ooecia of the two species are clearly different (those of *C. australis* are fully pseudoporous), but colonies without ovicells are readily distinguished by the much shallower sinus in *S. romajoyae*, avicularium shape and colony form. The small avicularia of *S. romajoyae* are subtriangular and widest proximally, whereas those of *C. australis* are narrowly triangular proximally and usually widest midlength. The large avicularia of *C. australis* are also narrowly triangular proximally, whereas those of *S. romajoyae* are elongate oval with parallel sides. The growth form of *C. australis* is a network of unilaminar tubes, whereas *S. romajoyae* is an encrusting species.

Stephanotheca romajoyae n. sp. has the smallest orifice of the *Stephanotheca* species (0.09 \times 0.10 mm), followed closely by *S. ipsum* n. sp. (0.10 \times 0.10 mm). The southern Australian species *S. ambita* and *S. victoriensis* also have smaller orifices than the European species (0.11 \times 0.11 mm, 0.11 \times 0.13 mm respectively vs 0.12–0.15 \times 0.13–0.15 mm).

Stephanotheca ambita shares with *S. romajoyae* n. sp. a wide shallow sinus, but it has smooth rather than serrate condyles and a single, small, oval suboral avicularium. *Stephanotheca victoriensis* has a larger, wider, distinctly oval orifice, and a single oval avicularium distant from the orifice and almost in the centre of the zooid.

Orificial dimorphism occurs in all *Stephanotheca* species except *S. perforata* (0.15 vs 0.15 mm; Reverter-Gil *et al.* 2012), but is most pronounced in *S. romajoyae* n. sp., with ovicellate orifices much wider than autozooidal orifices (0.14 vs. 0.10 mm). The ooecia of *S. romajoyae* differ from those of all known *Stephanotheca* species in being longer than wide. Ooecia of the Australian species differ in various ways from the typical crowned ooecium of the European species: those of *S. ipsum* n. sp. are ridged, those of *S. victoriensis* have a single row of pseudopores forming an arch and those of *S. ambita* have a relatively large perforated area and smaller, lower nodular rim of calcification. *S. romajoyae* ooecia are most similar to those of *S. ambita*, with a similarly wide perforated area.

Distribution. *Stephanotheca romajoyae* n. sp. is known only from the GoC, with four colonies collected from the same site at Bryomol Reef, east of Mornington Island at 33 m, and a fifth colony from southeastern GoC at 33 m.

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